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DETERMINATION OF SOFTENING TEMPERATURES OF POLYMERS

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Abstract. In this article, the softening temperatures of secondary polymer samples were studied by studying their physicomechanical and technological properties. The softening temperatures of polymers were studied in a Vicat / HDT laboratory device according to GOST 15088-2014 (ISO 306:2004). Based on the results obtained, the necessary conclusions were drawn regarding the structural-chemical composition and physicomechanical properties of secondary polymer waste, as well as methods for their processing. During the research, it was experimentally confirmed that the softening temperature of polymers depends on their molecular weight, degree of crystallinity, amount of plasticizers, and degradation states occurring during processing. It was found that chemical changes such as thermooxidation, chain shortening, or branching occurring in secondary polymers have a significant effect on the softening temperature. It was also noted that there is a certain correlation between the deformation indices under temperature (HDT) and the needle penetration temperature (Vicat). The experimental results showed that the softening temperature of recycled polymers can differ by 5–20°C compared to primary polymers, which is important in determining their operational properties and processing parameters. Also, specific ranges of softening temperatures were determined for different polymer categories (PP, PE, PS, etc.) and their behavior during regranulation was analyzed. These scientific results create the necessary basis for selecting high-quality processing technologies from secondary polymer resources, determining optimal heat loads, and using them to stabilize product quality.

Keywords: Vicat / HDT, secondary PP and PVC blends, plasticizer, dioctyl phthalate (DOF), PP + plasticizer, PVC + plasticizer, secondary PP and PVC blends + plasticizer.

Аннотация. В данной статье проведено исследование температур размягчения образцов вторичных полимеров путем изучения их физико-механических и технологических свойств. Исследования температур размягчения полимеров проводились на лабораторной установке Vicat/HDT по ГОСТ 15088-2014 (ISO 306:2004). На основании полученных результатов сделаны необходимые выводы относительно структурно-химического состава и физико-механических свойств вторичных полимерных отходов, а также методов их переработки. В ходе исследований экспериментально

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подтверждено, что температура размягчения полимеров зависит от их молекулярной массы, степени кристалличности, количества пластификаторов и деградационных состояний, происходящих в процессе переработки. Установлено, что химические изменения, такие как термоокисление, укорочение цепи или разветвление, происходящие во вторичных полимерах, оказывают существенное влияние на температуру размягчения. Также отмечено, что существует определённая корреляция между индексами деформации под действием температуры (HDT) и температурой проникновения иглы (Vicat). Результаты экспериментов показали, что температура размягчения вторичных полимеров может отличаться на 5–20 °C по сравнению с первичными полимерами, что важно для определения их эксплуатационных свойств и параметров переработки. Также были определены конкретные диапазоны температур размягчения для различных категорий полимеров (ПП, ПЭ, ПС и др.) и проанализировано их поведение при регрануляции. Данные научные результаты создают необходимую основу для выбора высококачественных технологий переработки вторичных полимерных ресурсов, определения оптимальных тепловых нагрузок и их использования для стабилизации качества продукции.

Ключевые слова: Vicat/HDT, вторичные смеси ПП и ПВХ, пластификатор, диоктилфталат (ДОФ), ПП + пластификатор, ПВХ + пластификатор, вторичные смеси ПП и ПВХ + пластификатор.

Annotatsiya. Ushbu maqolada ikkilamchi polimer namunalarining fizik-mexanik va texnologik xossalarini o‘rganish asosida ularning yumshash harorati tadqiq etildi. Polimerlarning yumshash harorati GOST 15088-2014 (ISO 306:2004) standartiga muvofiq Vicat/HDT laboratoriya qurilmasida aniqlanildi. Olingan natijalar asosida ikkilamchi polimer chiqindilarining strukturaviy-kimyoviy tarkibi, fizik-mexanik xususiyatlari hamda ularni qayta ishlash usullari bo‘yicha tegishli ilmiy xulosalar chiqarildi. Tadqiqot jarayonida polimerlarning yumshash harorati ularning molekulyar massasi, kristallanish darajasi, plastifikatorlar miqdori hamda qayta ishlash davomida yuz beradigan degradatsiya jarayonlariga bog‘liqligi tajriba yo‘li bilan tasdiqlandi. Ikkilamchi polimerlarda kuzatiladigan termo-oksidlanish, zanjirlarning qisqarishi yoki tarmoqlanishi kabi kimyoviy o‘zgarishlar yumshash haroratiga sezilarli ta’sir ko‘rsatishi aniqlandi. Shuningdek, harorat ta’sirida deformatsiya ko‘rsatkichlari (HDT) bilan igna botish harorati (Vicat) o‘rtasida ma’lum darajada korrelyatsiya mavjudligi qayd etildi. Eksperimental natijalar shuni ko‘rsatdiki, qayta ishlangan polimerlarning yumshash harorati birlamchi polimerlarga nisbatan 5–20°C farq qilishi mumkin.

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Bu esa ularning ekspluatatsion xossalari va qayta ishlash parametrlarini belgilashda muhim ahamiyat kasb etadi. Bundan tashqari, turli polimer turlari (PP, PE, PS va boshqalar) uchun yumshash haroratining aniq diapazonlari belgilandi hamda ularning qayta granulatsiya jarayonidagi xatti-harakatlari tahlil qilindi. Olingan ilmiy natijalar ikkilamchi polimer resurslaridan samarali foydalanish, optimal issiqlik yuklamalarini aniqlash, yuqori sifatli qayta ishlash texnologiyalarini tanlash hamda tayyor mahsulot sifatini barqarorlashtirish uchun zarur ilmiy asos yaratadi.

Kalit so‘zlar: Vicat/HDT, ikkilamchi PP va PVC aralashmalari, plastifikator, dioktil ftalat (DOF), PP + plastifikator, PVC + plastifikator, ikkilamchi PP va PVC aralashmalari + plastifikator.

INTRODUCTION

The softening temperatures of polymers were studied in a Vicat / HDT laboratory device according to GOST 15088-2014 (ISO 306:2004).

During the experiments conducted to study the softening temperatures of secondary waste, 3 samples were prepared and tested.

The thickness of the samples was taken as standard: sample 1 was 3.4 mm, sample 2 was 3.6 mm, and sample 3 was 3.5 mm. The experiment started at room temperature of 22.40°C. The heating rate of the apparatus was 500°C/hour. The time taken for the needle to penetrate 1 mm under a load (10 N) applied to sample 1 was 111.67 minutes, and the temperature at this time was 117.30°C.

1-experiment. Determination of softening temperatures of secondary PP and PVC mixtures obtained in equal amounts.

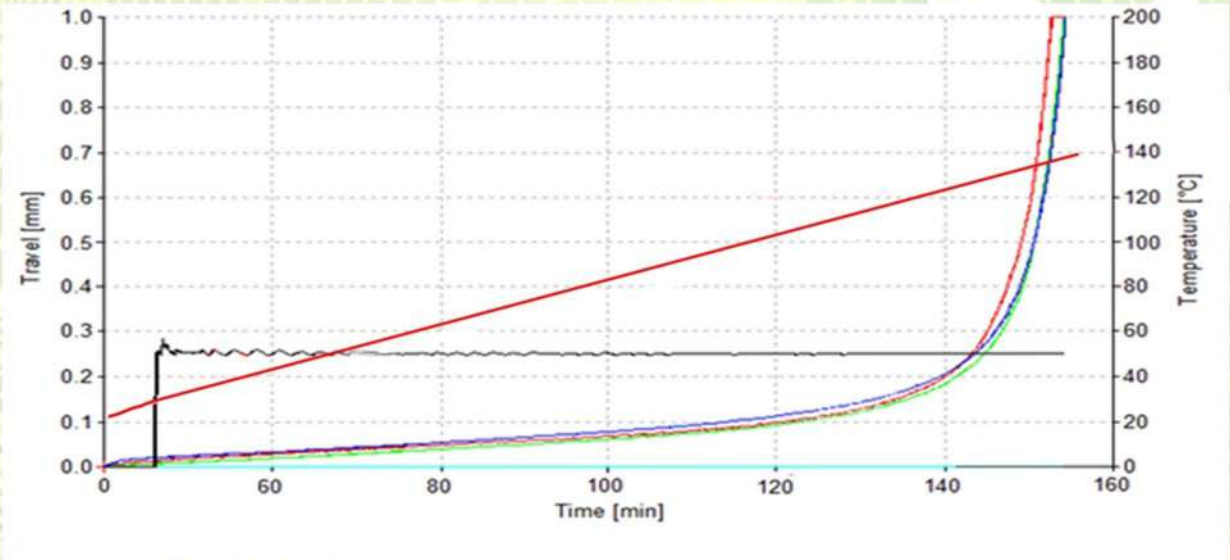


Figure 1. Softening temperatures of secondary PP and PVC blends.

EXPLANATION. The red straight line in the figure is the temperature of the device, and the green, blue and light reddish colors are the temperatures of three identical samples.

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2-experiment. Determination of softening temperatures of secondary PP and PVC mixtures + plasticizer (1:0.2 m.b.) obtained in equal amounts.

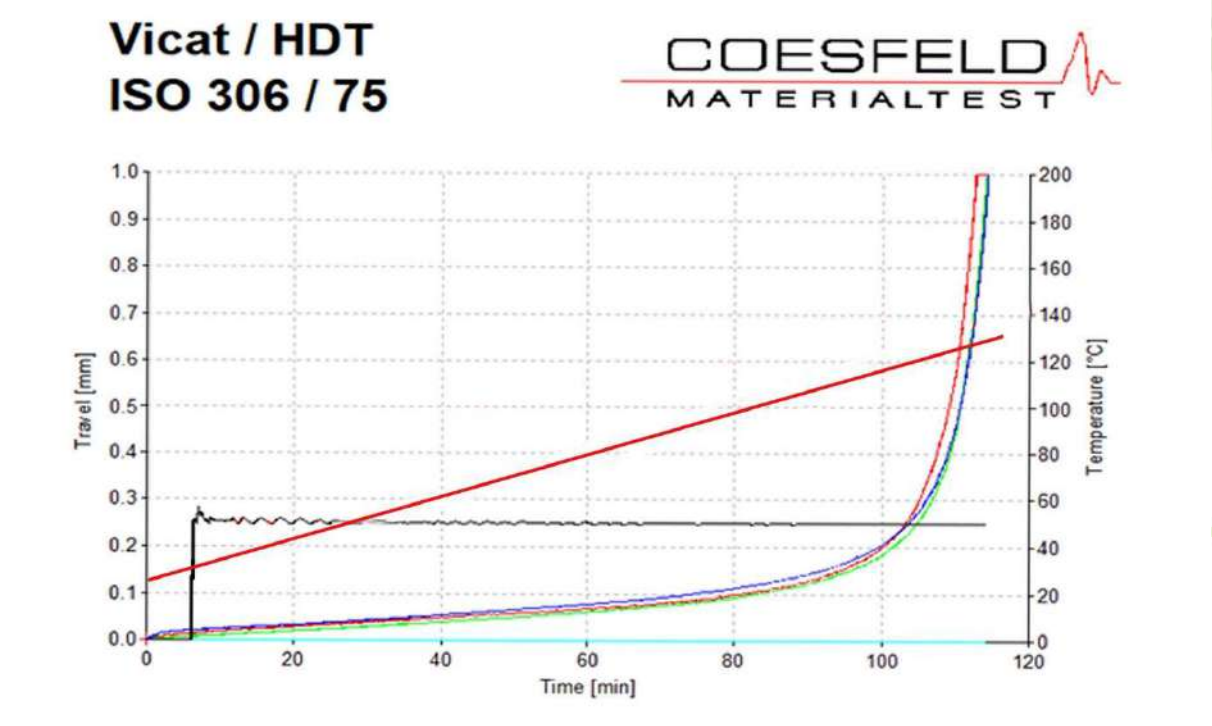


Figure 2. Softening temperatures of equal amounts of secondary PP and PVC mixtures + plasticizer (1:0.2 m.p.).

3-experiment. Determination of softening temperatures of secondary PP and PVC mixtures + plasticizer (1:0.5 m.p.) obtained in equal amounts.

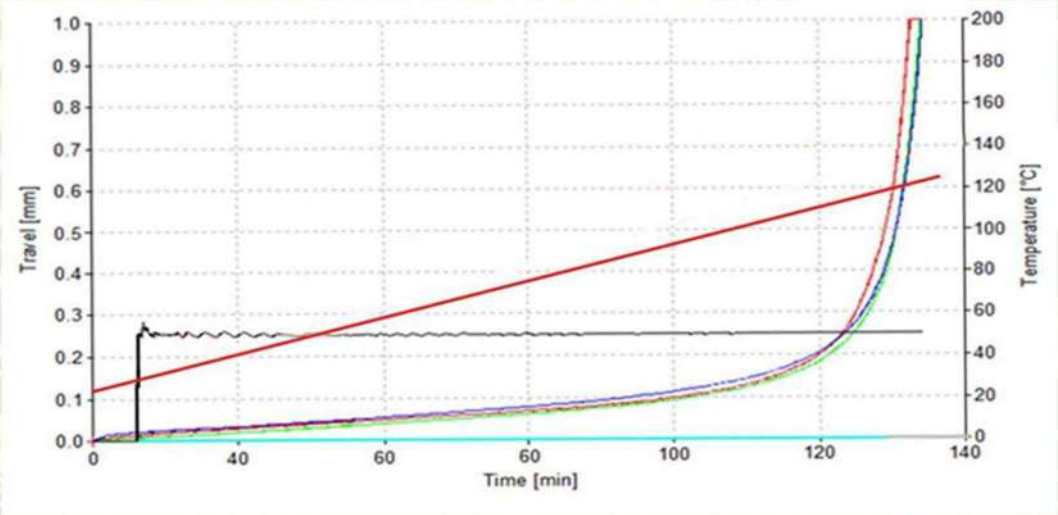


Figure 3. Softening temperatures of equal amounts of secondary PP and PVC mixtures + plasticizer (1:0.5 m.b.).

4-experiment. Determination of softening temperatures of secondary PP and PVC mixtures + plasticizer (1:0.8 m.p.) obtained in equal amounts.

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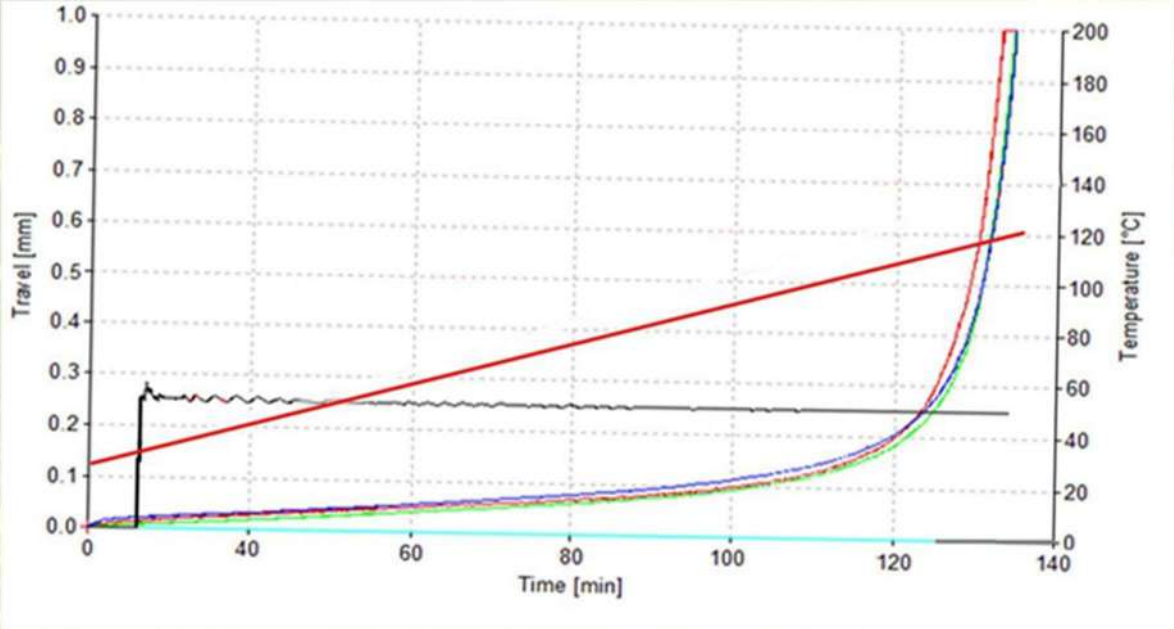


Figure 4. Softening temperatures of equal amounts of secondary PP and PVC mixtures + plasticizer (1:0.8 m.p.).

The results obtained during the study of softening temperatures of secondary waste are presented in Table 1:

Table 1

Softening temperatures of primary and secondary PP, PVC waste and their plasticized compositions

Names of polymers and obtained proportions of plasticizers	Softening temperature, 0C
Polypropylene	138
Secondary PP	134,5
PP + plasticizer; 1 : 0.2	129
PP + plasticizer; 1 : 0.5	123
PP + plasticizer; 1 : 0.8	119
PVC resin	104
Secondary PVC	124
PVC + plasticizer; 1 : 0.2	122
PVC + plasticizer; 1 : 0.5	118
PVC + plasticizer; 1 : 0.8	115,4
Secondary PP and PVC blends	141

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Secondary PP and PVC mixtures + plasticizer; 1 : 0.2	135,8
Secondary PP and PVC mixtures + plasticizer; 1 : 0.5	129,3
Secondary PP and PVC mixtures + plasticizer; 1 : 0.8	127

App. *Dioctyl phthalate (DOF) was obtained for the plasticization of secondary mixed PE, PP, PVC waste.*

As can be seen from Table 1, the softening temperatures of primary PP and PVC raw materials are higher than the softening temperatures of secondary PP and PVC waste (red straight line), and the softening temperatures of PVC waste are much lower, except due to various additives in its composition.

The composition of this secondary waste is 1:0.2; 1:0.5; It can be noted that their softening temperatures decreased when plasticizer (DOF) was added in 1:0.8% ratio.

Therefore, the mixture of plasticizers penetrates between polymer macromolecules, weakens their intermolecular forces of attraction (Vander-Waals), and as a result, the flexibility of the polymer increases to a certain extent, the molding properties during processing are improved, and the softening temperatures are reduced.

It is clear from this that the introduction of plasticizers into the composition of secondary PP and PVC-based waste makes it possible to produce various types of products from polymer waste.

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